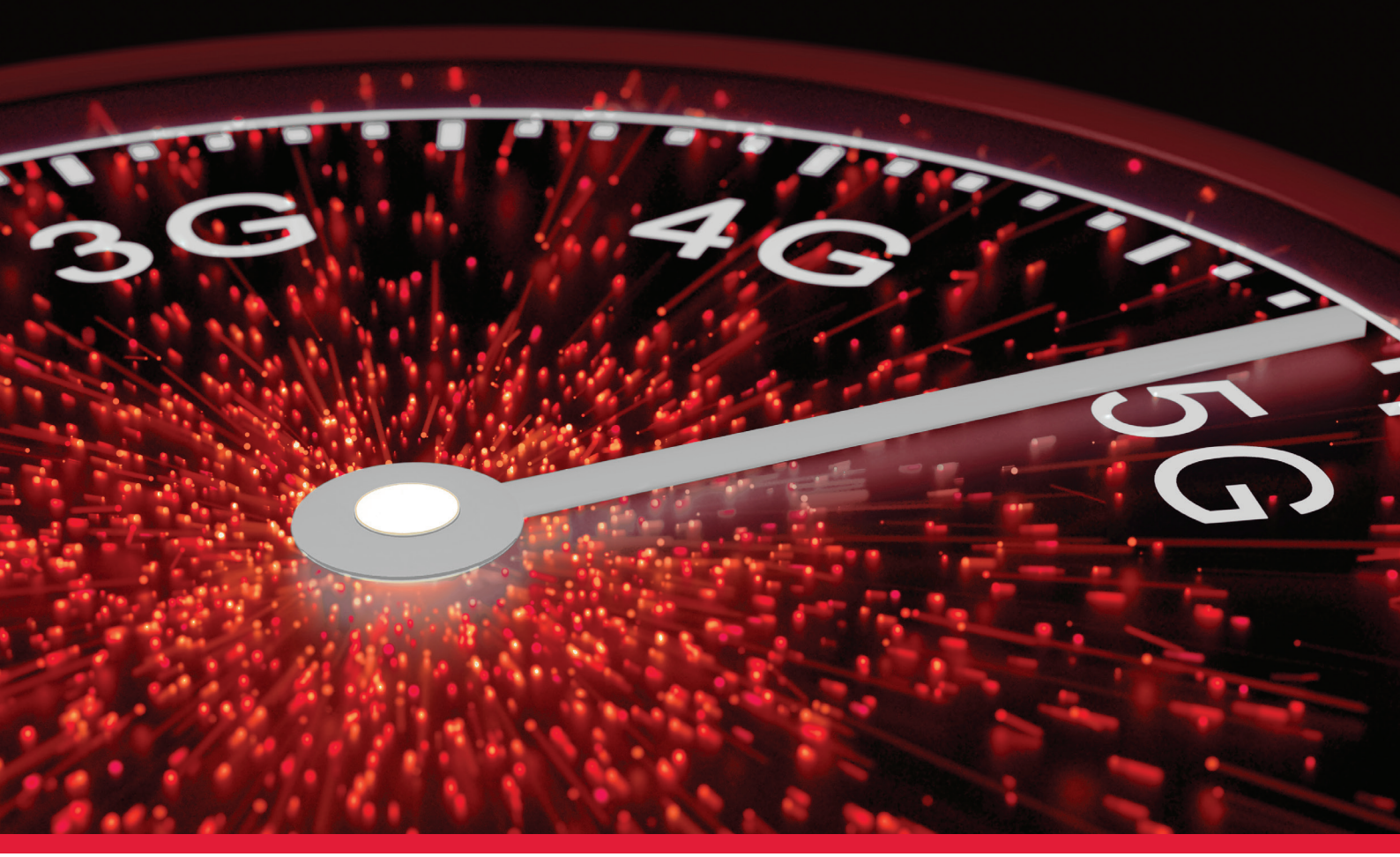

WHITE PAPER

5G Networks – Wireless and Fiber Backhaul Solutions

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Introduction

As Gigabit-LTE networks and 5G infrastructure trials are being deployed worldwide, the fiber versus wireless dilemma rises once again.

Network operators seek backhaul infrastructure that will accommodate the exponential growth of their capacity needs, growing from 10s of Mbps in 3G networks to 100s of Mbps and even a few Gbps in LTE, LTE-Advanced and LTE-Advanced Pro networks and estimated to grow to 10s of Gbps in 5G applications. On the other hand, these backhaul solutions also need to be cost-effective to deploy and should provide fast time-to-market for new services and target markets, as networks expand and become denser.

In light of these requirements, there are two main alternatives for backhaul infrastructure: fiber and wireless. Both of them are valid and key for the deployment of Gigabit-LTE and 5G networks. The hybrid backhaul infrastructure, which combines both fiber and wireless technologies, offers the greatest value to mobile network operators.

This white paper includes an overview of each technology and describes the factors to consider when selecting the right technology for each network scenario.

What to consider when selecting the right solution for each network scenario

Wireless backhaul and fiber backhaul technologies differ for most parameters. Yet, both are aimed at achieving the same goal – creating a transport infrastructure to accommodate current and future needs for capacity, latency and availability of services provided over the mobile network.

When exploring the two technologies, there is a need to examine them in light of the relevant parameters. In the context of the 5G network and services, those parameters should reflect the main challenges and goals of 5G deployment. The following parameters reflect those challenges and are a good base for such an analysis:

- Time-to-market – Is the solution easy and fast to deploy so that the network densification process, which is required when moving to 5G, can meet the time-to-market targets?
- Highly reliable – Will the solution allow the service provider to meet the stringent SLA requirements for mission critical 5G services?
- Flexible and scalable – Can the solution support future capacity growth?
- Cost efficient – Will the solution support the business targets of the mobile operator?

Next, we will examine each technology in light of the abovementioned parameters.

Wireless and fiber backhaul technologies

Fiber-based solutions involve the deploying a fiber infrastructure or the leasing of a fiber (dark-fiber), a wavelength or a certain capacity, from a third party who already owns a fiber infrastructure.

These two options differ greatly in relation to some of the parameters we have already defined for our analysis. For time-to-market, leasing is a superior alternative assuming that the third-party operator from whom the capacity is leased already has a ready-to-use infrastructure in the required locations.

In terms of cost efficiency, there is a major difference between the options, both in terms of total cost of ownership (TCO) and in terms of the CAPEX-OPEX split. This is because laying down fiber is a CAPEX-focused approach and leasing fiber or capacity relies heavily on OPEX.

If we examine the four different options for implementing a fiber-based solution – deploying fiber, leasing fiber, leasing capacity or deploying a wireless solution – then we get an extensive view of each option. The following table summarizes this evaluation.

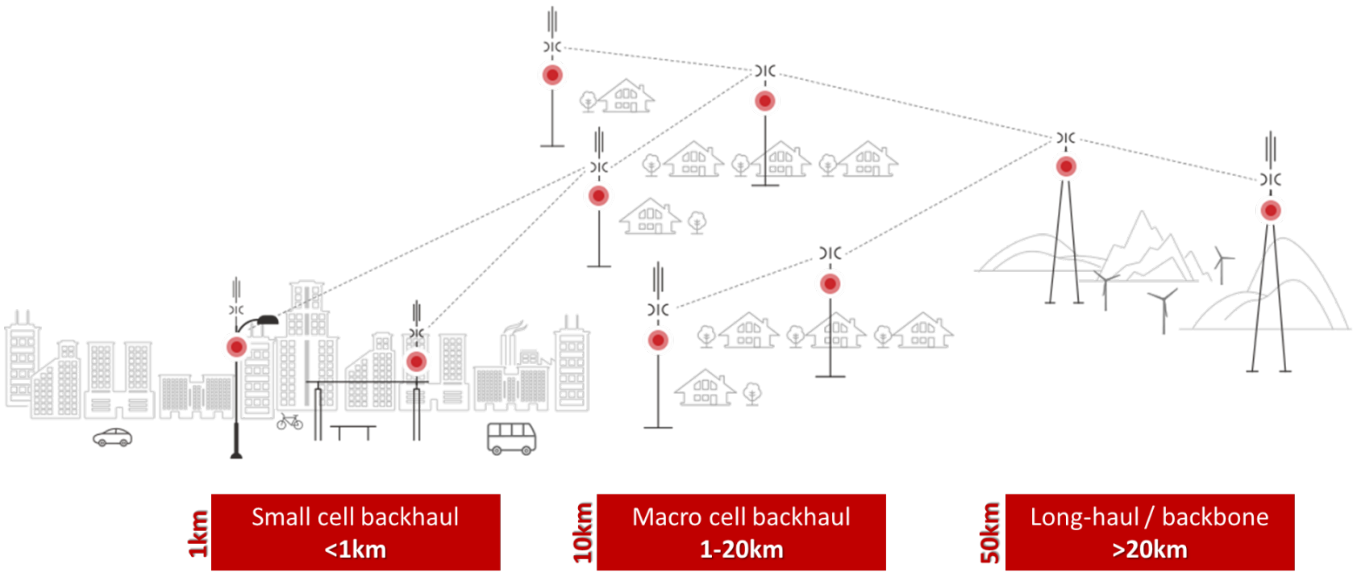
	Time-to-market	Highly reliable	Flexible and scalable	Cost efficient
Fiber	Time-consuming to deploy and commission. Involves acquiring "rights of way" and work permits. **Months**	Vulnerable to fiber cuts if not deployed in a redundant architecture (e.g. ring). **99.9% availability (without protection)**	Highly scalable & very easy to upgrade capacity. Practically limitless capacity. **>1Tbps**	Large one-time investments.
Dark fiber	Time consuming to commission as it needs active optical equipment at each end. Typically, not available where needed. Dependent on a 3rd party. **Weeks-months**	Vulnerable to fiber cuts if not deployed in a redundant architecture (e.g. ring). **99.9% availability (without protection)**	Scalable, but dependent on a 3rd party. Practically limitless capacity. **>1Tbps**	Large one-time fee (equipment and initial fiber IRU fee) as well as recurring investment (fiber lease).
Leased line	Medium time consumption – assuming service is available where needed. Dependent on a 3rd party. **Days-weeks**	Typically, under SLA that assures alternate route in case of failure. **99.99% availability**	Limited scalability, dependent on a 3rd party. Practically limitless capacity – dependent on 3rd party infrastructure. **10-100Gps**	Low one-time investment with relatively high recurring fees and additional one-time fees for upgrades.
Wireless transmission	Very quick to deploy assuming frequency allocation and equipment are available – feasible days. **Days-weeks**	High-availability. **99.999% availability**	Highly scalable & very easy to upgrade capacity. Capacity future limit is 100Gbps. **10-100Gbps**	Pay-as-you-grow investment. Medium one-time fees. Minor recurring expenses (spectrum) and modest upgrade costs.

The costs angle

In order to understand the cost-effectiveness of each solution, we need to take a closer look at the cost structure of each technology:

- **Fiber deployment** requires large CAPEX and OPEX investment on Day-1, as it requires laying down fiber infrastructure at the required route and installing end-devices, which could vary from Optical Terminal Multiplexers, implementing DWDM, to routers or switches, at each end of this route.
- **Dark-fiber lease** turns the fiber cost into recurring OPEX but still requires investment in end-devices.
- **Capacity lease** is a pure OPEX model and is mostly recurring, with possible installation and upgrade one-time fees.
- **Wireless backhaul** requires end devices (wireless nodes) as well as site acquisition costs, though these are typically sites which exist for the RAN infrastructure.

Next, we will examine the cost of deploying wireless backhaul or a fiber-based infrastructure for link lengths of 1km, 10km and 50km and for future-ready capacity requirements (i.e. 1Gbps, 4Gbps and 10Gbps) as they are illustrated in typical use cases in the following diagram.



As a typical solution for wireless backhaul, the following configurations were used:

- 1Gbps – for typical small cell backhaul - short distance (i.e. 1km), achieved by utilizing E-Band (for lower spectrum costs), while 10km macro-cell backhaul and 50km backbone links were achieved using MW bands, with either 1x56MHz channel, utilizing XPIC, or 1x112MHz channel, without XPIC.
- For 4Gbps – small-cell backhaul achieved by utilizing E-Band and for a macrocell and backbone, a 4x4 LoS MIMO configuration was assumed in MW bands, utilizing a single 112MHz channel.
- For 10Gbps – a small-cell backhaul is served with a single E-Band link utilizing a 2GHz channel. For macro-cells, the same carrier is combined with a microwave carrier in a multiband configuration.
- For 10Gbps – at the backbone / long-haul, a 10-carrier trunk was considered, utilizing 5 111MHz channels.

The following table includes a summary of the costs for each solution over a 3-year life-cycle.

(USD)	Fiber backhaul			Wireless backhaul		
Distance/ capacity	**1km**	**10km**	**50km**	**1km**	**10km**	**50km**
1Gbps	130K	1180K	5822K	55K	58K	61K
4Gbps	130K	1180K	5822K	55K	105K	115K
10Gbps	130K	1180K	5822K	55K	210K	215K

The practical angle

In addition to the cost-effectiveness analysis per cell-site, mobile operators and specifically those who provide multi-play services, need to consider additional factors as to whether fiber and/or wireless is the right solution for each network scenario. This section includes details about each of these factors.

Feasibility

One parameter to consider is the feasibility of each alternative. While our previous analysis assumes all options are valid, this is not true in all cases.

Parameters such as geography and accessibility can eliminate an option to deploy fiber in rural areas. This could also be the case in urban areas where right-of-way cannot always be acquired.

For Gigabit-LTE and 5G deployment scenarios, an operator's main focus is network densification in urban hot-spots, as well as the extension of the network coverage to not-spots. In both cases, fiber deployment is common unfeasible, and this leads many such operators to rely heavily on wireless backhaul for such network evolution.

Additional service potential

On top of the basic need for mobile cell site (or aggregation site) connectivity, which could be accommodated by each alternative (in most cases), there are cases where the selection of a specific solution may allow for additional services. This is relevant to operators who practice multi-play or quad-play (that is, in addition to their mobile offering, they also offer additional fixed voice, video and data services).

In these cases, if a quad play requires more than a 100Gbps per link, then fiber may be chosen over wireless even if the cost effectiveness criteria leans towards a wireless solution. This is because a fiber-based solution may enable additional services that the wireless solution does not.

Such a case calls for the inclusion of a revenue-gain parameter, in the standard cost-effectiveness selection process.

Latency considerations

Mission-critical public-safety applications, as well as trading applications and future applications such as V2X (vehicle to everything), are commonly grouped as Ultra Reliable Low Latency Communications (URLLC) and require strict latency performance, which could be tight as 5ms end-to-end latency.

Where such applications are present, a wireless backhaul solution may be required as its inherent, as well as practical latency figures are significantly lower than the ones of a fiber based backhaul.

The reasons for lower latency in wireless backhaul are:

- Propagation speed, which is faster for EM waves in air compared to light in fiber
- Reflection of light inside the optical fiber (even in a single-mode fiber), causing a longer path than the actual fiber length
- Length of the fiber route is typically greater than that of the wireless link as it is not a direct route
- Fiber route typically introduces more nodes, which add latency

These are all relevant to FDD wireless applications. In some cases, the TDD-implementation of millimeterwave wireless backhaul solutions is available but they do not suit a URLLC service.

Gigabit-LTE and 5G backhaul – wireless & fiber

As mentioned earlier in this article, fiber backhaul and wireless point-to-point connectivity are key to Gigabit LTE and 5G network evolution, just as they are an important pillar in 3G and 4G-LTE backhaul infrastructure.

When planning and implementing such an evolution, the trade-off between the practically-limitless capacity available with optical fiber and merits of wireless backhaul (cost-effective, easy and fast to deploy, highly-reliable and scalable) need to be weighed on a case-by-case basis. This is due to the variety of requirements across different Gigabit-LTE and 5G network domains and deployment scenarios, varying from dense-urban and massive deployment of small-cells, through to busy and loaded aggregation sites and high-capacity, long-reach backbones.

The result of such a strategy is a combination between fiber backhaul and wireless backhaul, which can be achieved based on several domains:

- **Sub-network domain**: the decision about the type of transmission is based on the sub-network. Core and backbone sites are covered with fiber as they are less geo-dynamic and require higher capacity. Access and aggregation sites are connected with wireless backhaul which fits the agile nature of these sub-networks, particularly as the cell-site grid densifies as we move to higher capacity requirements and millimeterwave frequencies RAN in 5G.
- **Time-capacity domain**: wireless backhaul is commissioned first to any site in the network, for cost-effectiveness and time-to-market, and then later a fiber connection is established is required. The fiber backhaul timing is based either on the time it takes to deploy the fiber infrastructure (in case of ultra-high capacity requirements on day-1) or on the growth in capacity requirement. Once a fiber connection is established, the wireless connection can be relocated to a new cell-site or maintained as a secondary, resilient connection to ensure high availability, which is extremely important for 5G Ultra Reliable Low Latency Services (URLLC).
- **Service-redundancy domain**: this is typically implemented in the backbone and in sites running high-priority traffic (in particular, in the case of 5G URLLC). The wireless backhaul serves here as a completion to a ring topology or as a 1+1 backup to a fiber backhaul.

However, in practice, as networks densify and extend mostly in urban areas, wireless backhaul is often the only viable option. This calls for an ultra-high capacity wireless backhaul:

A millimeterwave link that can scale up to 40Gbps, and with future, high-frequency D-Band up to 100Gbps.

Alternatively, for longer paths, a 4x4 LoS MIMO microwave connection can be used as it scales up to 4Gbps.

In the case of backbones that connect cities, data-centers, and network segments, a multicarrier trunk can be used as it can scale up to more than 10Gbps with an extremely long reach.

The use of such an ultra-high capacity wireless backhaul technology also offers an alternate path, even if fiber already exists. This is crucial for cases such as fiber cuts as it eliminates the need for doubling the investment in fiber infrastructure.

To conclude, when planning your network evolution towards Gigabit-LTE and 5G, high-capacity wireless backhaul, combined with fiber where available, allow you to leverage the strengths and benefits of each technology while keeping your business plan intact.

About Ceragon

Ceragon Networks Ltd. (NASDAQ: CRNT) is the world's #1 wireless backhaul specialist. We provide innovative wireless backhaul solutions that help mobile operators and other service providers increase operational efficiency, ensure peace of mind, and enhance customers' quality of experience. We serve wireless service providers, public safety organizations, government agencies and utility companies, which use our solutions to deliver 4G, mission-critical multimedia services and other applications at high reliability and speed.

Ceragon's unique multicore technology provides a highly reliable, high-capacity 4G wireless backhaul with minimal use of spectrum, power and other resources. It enables increased productivity, as well as simple and quick network modernization. We deliver a range of professional services that ensure efficient network rollout and optimization to achieve the highest value for our customers. Our solutions are deployed by more than 460 service providers, as well as hundreds of private network owners, in more than 130 countries.